SEAGULL TECHNOLOGY, INC.

16400 Lark Ave., Los Gatos, CA 95032-2547
Tel: (408) 358-7100 • Fax: (408) 358-7071

6 July, 1998

Development of Free Flight Simulation Infrastructure
Fiscal Year 1998 Research Task Order #3
NASA Advanced Air Transportation Technologies (AATT) Program

Detailed Implementation Plan

Honeywell Subcontract No. 8021308 A
NASA Prime Contract No. NAS2-98001

Seagull Technology Project No. C175.3

Delivered electronically to:
Bill Corwin, corwin_bill@htc.honeywell.com
Barbara J. Sweet, bsweet@space.honeywell.com

Prepared by:
F. McLoughlin, Seagull Technology
E. S. Miles, Seagull Technology

Development of Free Flight Simulation Infrastructure

Detailed Implementation Plan

This document serves as the "Detailed Implementation Plan" deliverable for NASA AATT FY98 RTO #3 regarding the "Development of Free Flight Simulation Infrastructure". It results from Seagull Technology's modification of the associated "Draft Implementation Plan" per NASA's comments as received electronically by Seagull from the prime contractor, Honeywell Inc., on 26 June 1998.

1. Background

1.1 Technical Issue

Seagull Technology proposes to lead a team that will architect, develop, and integrate simulation software/ hardware infrastructure at LaRC that will enable the evaluation of fundamental Free Flight issues. Free Flight and its implementation will be an immense challenge. Simulation infrastructure that suitably models Communications/ Navigation/ Surveillance (CNS) and flight deck-ATC-AOC components, initially at a high-level, will enable the exploration of important Free Flight issues. This, in turn, enables an understanding of the efficacy of proposed concepts and will lead to suggestions and investigations of alternative approaches. Furthermore, a highly-modular and open-architecture simulation will facilitate simulation evolution as concepts arise and/or mature.

To succeed, it is important for the development *team* to have both: (1) an appreciation for and experience with modular, open-architecture aviation software systems, and (2) domain knowledge of existing flight deck, ATC, and AOC implementations, as well as candidate advanced implementations, including decision support tools (DSTs).

1.2 Objective

Our objective is to implement a highly-modular real-time simulation architecture that will enable (a) investigation of Free Flight concepts in FY99, and (b) provide a growth path to more sophisticated and detailed models. The tools will include models of advanced flight deck and ATC interaction to provide a means to examine and refine fundamental Free Flight concepts and issues (note: AOC interaction will begin to be modeled in FY99). We will emphasize rapid development: (a) with an expandable architecture; (b) by leveraging COTS Unix (Sun, SGI) and WinNT (PC) development tools; and (c) by leveraging existing and imminent elements (cf. RTO#5, PAS/PASCAD, GAIMS, FASTWIN, AOL).

Figure 1 provides a high-level overview of the envisioned simulation infrastructure to be mechanized at LaRC. Elements of a "tactical pseudo-pilot/pseudo-controller capability" will be implemented. Advanced free flight concepts for CNS, ATM, AOC, flight deck, and weather can be simulated with additional funding.

<u>Retain Traceabilty to Existing and Emerging Standards:</u> Seagull is familiar with and will evolve simulation infrastructure that is traceable to nationally recognized standards and reports that are shaping free flight. These include NASA AATT project reports, the National Airspace System Architecture (NAS; v3.0 latest), the Federal Radio Navigation Plan (1996), and applicable RTCA documents ("An Evolutionary Operational Concept for Users of the NAS", 6/18/97). We will remain abreast of free flight concepts, applicable aviation standards, and FAA plans.

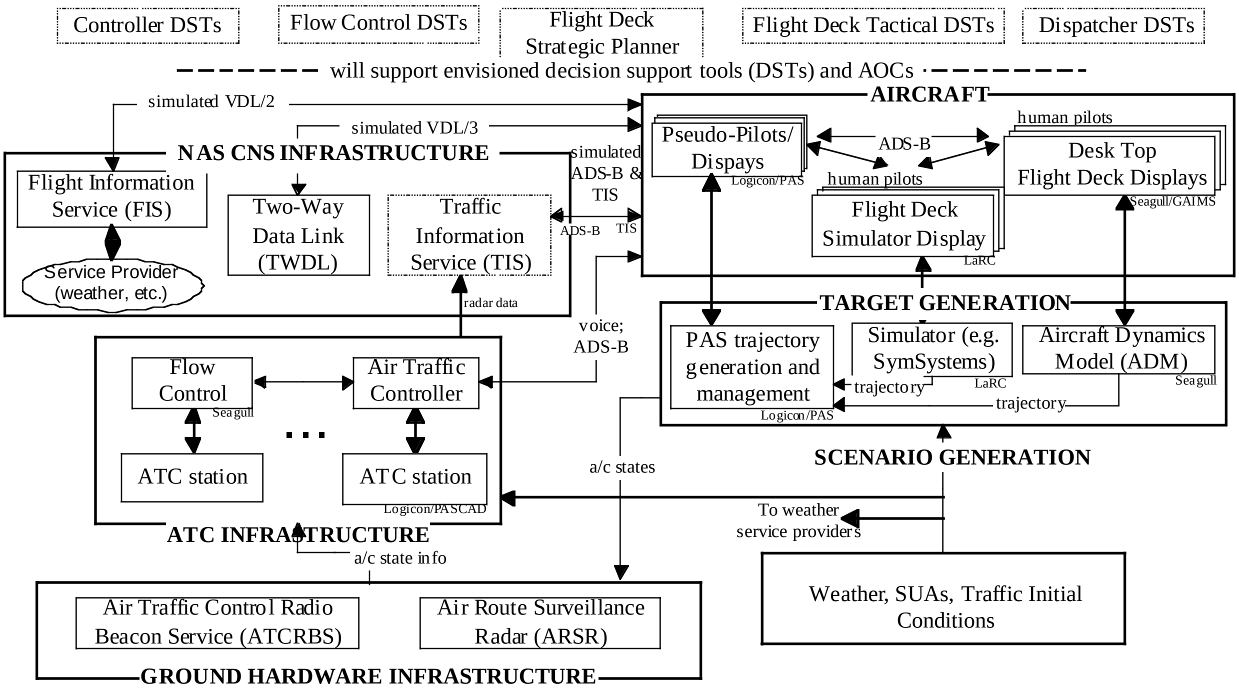


Figure 1. Summary of proposed simulation infrastructure objective. LARCNET-compatible interfaces enable participation from simulated pseudo-controllers and pilots, researchers interacting as pilots (desk tops) and eventually simulator pilots. Scenario generation and data logging are integral with system elements.

1.3 Technical Approach

This section identifies and describes the principal tasks for this Phase I activity.

TASK - Develop an Implementation Plan:

This document is the implementation plan. It summarizes the plan for the program with a schedule that lists activities and milestones in greater detail than the proposal in response to the RTO. To develop this plan we have:

- met with and discussed generic interface issues and timelines with the task leads for RTO #5(a) (Lockheed Martin, ASI regarding their Pilot Associate / Shared Model of Intent software) and RTO #4 (Honeywell, Flight Planning/Re-planning)
- met with the software developers of PAS/PASCAD at subcontractor Logicon regarding the status of their tools and the deliverables we expect. Logicon has a new task lead, Mr. Elliott Smith, with whom we will meet.
- surveyed existing simulations and development tools;
- explored issues regarding the technical compatibility of our software with existing and near-term-envisioned simulation and decision support tool elements;
- iterated candidate architectures that address the simulation infrastructure goals.

We will provide a preliminary implementation plan to NASA. By fifteen (15) working days after NASA's written approval of the preliminary plan we will provide a final implementation plan in response to NASA's comments about the preliminary plan.

TASK – Develop Quality Control Plan:

We will provide a preliminary quality control plan to NASA. By fifteen (15) working days after NASA's written approval of the preliminary plan we will provide a final quality control plan in response to NASA's comments about the preliminary plan. The plan will be based upon a suitable outline provided by NASA that identifies the desired content.

TASK - Recommend Hardware/Software Purchases:

The Free Flight Simulation Infrastructure will be architected to leverage COTS tools and existing simulation capabilities at NASA, FAA and industry. The hardware and software requirements will reflect this design philosophy. An emphasis will be placed on open-system standardization and multi-platform compatibility. The preliminary architecture design includes SGI computers to leverage existing systems at Langley's IDEAS laboratory and CTAS, Sun workstations to leverage PAS development, and NT-class PCs to utilize FASTWIN and Seagull display capabilities. Seagull delivered recommended hardware and software procurements to NASA per the research task order.

TASK – Pursue Compatibility with Airspace Operations Lab (AOL)

The Free Flight Simulation Infrastructure will pursue compatibility with AOL. Specifically, we will pursue the use of CTAS and related modules in Phase I, and will plan for the incorporation of CTAS in future phases. To maintain compatibility with PAS, we will pursue the use of CTAS with the Input Source Manager (ISM). To maintain compatibility with IDEAS lab, we will pursue the use of CTAS on SGI platforms.

TASK - Survey Existing Simulations Components:

Seagull will leverage existing simulations or associated components to the extent that:

1. they provide the desired flight deck, AOC, ATM, or traffic flow management functionality;
2. they run on platforms and operating systems we will use;
3. their interfaces and input/output suit the modular simulation architecture; and
4. the technology simulated has growth potential to expected free flight paradigms.

There are numerous simulation components that we are considering, including, but not limited to:

- PAS (Pseudo Aircraft Simulation),
- CTAS,
- TracView,
- FASTWIN (FMS model; CDU/PFD/MFD),
- ODS (Operator Input and Display System),
- FIRST*plus*, cockpit simulators,
- PC-based AEROWINX "747-400 Precision Simulator" for high-end pseudo-pilot station interface
- NASA's Airspace Operations Laboratory (AOL),
- NASA's Stone Soup simulation components,
- NASA's Part Task simulation components,
- Seagull's GAIMS multi-function display (MFD) software,
- Virtual Prototypes' STAGE and FLSIM tools,
- Jeppesen aircraft simulation hardware and software,
- The FAA Technical Center's Target Generation Facility (TGF),
- EUROCONTROL simulation architecture (e.g. their CORBA-based simulation infrastructure), and
- Existing communications protocol and software (e.g., CORBA, HLA, DIS, NDDS, straight TCP/IP).

TASK – Aircraft Modeling:

Four-Dimensional (4D) point-mass aircraft performance models will be utilized to simulate individual flights. In addition to 3-D translation, the aircraft roll orientation is included in the performance model. Aircraft mass is the only inertial term considered.

In Phase I, the single-aircraft pilot stations will include performance models for a Boeing 757, Boeing 737, and a McDonnell Douglas MD-11. In Phase II, performance models for a commuter turboprop and high-speed subsonic aircraft will be considered.

The pseudo-aircraft can draw from performance models taken from a lower-fidelity database of 367 available aircraft.

TASK – Develop Architecture:

We will employ a highly modular, upgrade-able architecture, and we will publish and maintain interface definition documents.

Modularity*:* We will define a simple, object-oriented model of all simulation elements: flight decks, ATC/ATMs, AOCs, TFM, and datalink. As/when applicable. Many of the fundamental technologies that enable free flight are associated with *information* transfer, processing, and display. Examples include GPS (an information source), air-air and air-ground communications (e.g., ADS-B, VDL datalink, ACARS), and existing and emerging information processing algorithms (e.g., collaborative decision making; conflict detection and resolution). Furthermore, free flight concepts will largely evolve around what information is available, what is communicated (air-air, air-ATC, air-AOC, ATC-AOC), how it is communicated (link properties, including range, latencies, integrity properties), and where it is processed (flight deck, ATM, AOC). We will consequently structure an information-centric object-oriented design that it is both applicable to simulating free flight concepts and leading to a naturally evolving NAS architecture. The architecture we develop shall have growth potential to envisioned Free Flight concepts, but will be initially responsive to this Phase I development activity, including the near-term integration of RTO #5 product(s) and subsequent integration of RT0 #4 products.

Interfaces*:* We will implement the highly-modular software as separate processes. This approach has the following advantages:

1. Various subsets of modules can be used for various types of testing - desktop, lab, simulator, or flight.
2. Each process has its own diagnostics (isolated validation; debugging) and data logging (post test analyses).
3. Modules can be evolved by separate organizations that have management responsibility and/or unique expertise with a module's functionality.
4. Different modules can execute on different processing platforms as needed to exploit operating system, processing, or application software tools. Inter-platform communications (e..g sockets with TCP/IP) can be exploited to realize communications.
5. Multiple instances of modules with the same global functionality can be developed [by multiple organizations] and tested to see which works best.
6. If a module 'crashes', it does not bring down the whole system. This will save time and other resources.

To allow the multiple processes to interact, we will specify, test, and maintain inter-process communications and associated documentation. The principal initial interfaces realized will be between the information management architecture, PAS software, CTAS software, FASTWIN software, and the results of RTO #5(a) and RTO #4. We will define generic interfaces with related RTOs, but will focus initial attention upon implementing and testing interfaces with RTO5(a). We will define interfaces so that information content and data transfer properties properly simulate reality to the desired fidelity. This can be done with COTS development tools. Seagull will exploit its experience and software tools for PC and UNIX-based inter-process communications, including sockets (TCP/IP), CORBA, shared memory (with appropriate alerting), and directory files to realize the needed interfaces. CORBA is the baseline (starting point) interface mechanism for structuring the transport of shared information; it has bridges to DIS and HLA and has been used by EUROCONTROL for very similar simulation infrastructure development.

<u>TASK – Develop Information Management/Communication Software:</u>

The two key software development activities for Phase I are:

1. The specification, realization, validation, and maintenance of inter-process/platform interfaces among the principal Phase I elements, namely:
   - Aircraft dynamic model software,
   - Pilot stations and displays,
   - Pseudo-Pilots,
   - ATC stations,
   - Service providers (e.g. Flight Information Services),
   - Conflict detection and/or resolution decision support tool instantiations; initially Pilot Associate / Shared Model of Intent,
   - Communications elements; and
2. The development of the communications infrastructure software that implements the information management architecture model.

The objective of this latter activity is functional software that enables a broad array of information/communications transfer. We will realize software that accommodates two-way addressed, multi-cast, and broadcast communications. A global objective is to evolve to accommodate current and near-envisioned communications among the major ATC-Cockpit-AOC elements (e.g. ADS-B, TIS, FIS, CPDLC, ACARS), while retaining generality for growth to longer-term concepts.

<u>TASK – Pilot Station Interface Software:</u>

The presence of individual pilot stations allows investigation of research issues associated with a particular aircraft instance. Algorithmic and human factors issues can be explored in more detail or more specifically than the more global Free Flight investigations that can take place with digital or pseudo-pilots. Research areas such as cockpit display of traffic, weather display, controller/pilot data link communications, and general situation awareness issues can be explored with a pilot station.

Consistent with the rapid-prototyping philosophy, we will use PC-based tools to evolve pilot stations. Our top two candidate tools for pilot station displays are: (1) NASA's FASTWIN software and (2) Seagull's GAIMS software. FASTWIN has a good fidelity CDU, and primary and multi-function displays. GAIMS is a flexible multi-function display that has an API to interface with navigation, weather, traffic, and CPDLC display processes. Both software packages run on Windows NT. For Phase I, our plan is to use FASTWIN's CDU, FMS, PFD, and Nav display elements. Low-fidelity pilot interface devices will be investigated and used as appropriate (we will even consider the well-standardized and mature flight simulator game industry).

The aircraft dynamics for each pseudo-pilot station will be modeled nominally by interaction with the aircraft modelled in PAS, and alternatively by Seagull's Aircraft Dynamics Model (ADM) software. For the latter case, Seagull will specify to Logicon the specific functional modifications to PAS to realize the desired functionality. The aircraft dynamics modeling software (whether PAS, ADM, or otherwise) must accommodate external commands to change an aircraft's state. This is fundamental to successfully incorporating both active pilot stations, and the commanded changes to an aircraft state, such as will be output from DST software (e.g. RTO #5).

TASK – Realize Interface to RTO #5 Software:

We will develop a generic interface to flight deck decision support tools for conflict detection and resolution. Our initial instantiation will be with Lockheed-Martin's Pilot Associate software for shared intent information (RTO #5(a)). The requirements for this interface will be defined and evolved through telecons and e-mail communications. The specific data requirements will be implemented in a phased approach, starting with the necessary data for critical functionality. An initial interface definition will be initially established. The interface definition will specify the communications transport mechanism, data types and content, message formats, update rates, and latency requirements. Software to test and validate this interface will be exchanged between Seagull and Lockheed-Martin.

The initial RTO #5 interface for basic functionality in Phase I experiments is expected to include the following input object types (cf. Lockheed-Martin's applicable Final Report): (1) aircraft data, (2) ATC messages, (3) Flight Plans, and (4) Proximate aircraft. Expected initial outputs from RTO #5(a) include: (1) Operator Plan Assessment Logic (OPAL) messages, (2) Plan-Goal Graph (PPG) messages, and (3) aircraft commands in the form of flight plans.

TASK – Scenario Generation Development:

Scenario generation will include scenarios for traffic, weather, and special-use airspace. PAS will be utilized for its traffic-generation capabilities to establish initial aircraft trajectories and nominal flight plans for approximately 30 pseudo-aircraft for Phase I simulation experiments. FASTWIN will be used for three pilot stations.

TASK – PAS, PASCAD, and Components:

Pseudo Aircraft Systems (PAS) for ATC: We plan to use PAS and its interfaces to controller and pilot stations, sending the aircraft states to the controller stations for display. PAS has a link to today's radar driven ATC stations, but has growth capability to emerging tools like CTAS. PAS accepts as input pilot commands from pseudo pilot stations or trajectory states from cockpit simulators. The PAS interfaces are a key part of the software integration; they must be well understood and documented for a successful simulation. Several clients can connect to PAS using CTAS, DIS, or PAS protocols. All clients connect to PAS at the HOST emulator (HE) process. The HE translates and coordinates all communications with third-party clients. Inputs to HE pass through and are sent out to the receiving clients (CTAS, FAA, and PASCAD) with the PAS system updates.

For this effort, Seagull requests the following from Logicon:

1. generate a detailed interface control document (ICD) for PAS, PASCAD, and related core modules;
2. execute and validate specified modifications to PAS, PASCAD, and associated modules to accommodate the outputs of the pilot stations and flight-deck decision support tools for conflict detection and resolution, and flight planning;
3. provide detailed aircraft dynamic models;
4. maintain a PAS baseline; and
5. provide ongoing PAS integration support.

TASK – Establish RTO #4 Interface:

The interface to Honeywell's strategic flight [re-]planner work (RTO #4) will be architected but not exercised during Phase I. We will remain abreast of Honeywell's development efforts. Seagull and Honeywell personnel met at Seagull in early May to establish a mode of cooperation and explore the scope of the output of RTO #4. The principal of objectives of our Phase I activity with respect to RTO #4 are:

1. Understand the projected functional requirements for RTO #4 so that the resulting simulation infrastructure remains compatible. RTO #3 must be sufficiently general to accommodate the range of possible results from RTO #4.
2. Identify projected input/output requirements, including data content, update rate, latency requirements, transport mechanism, etc.; and
3. Understand the projected computing needs for RTO #4.

<u>TASK – Validate Infrastructure at Seagull:</u>

A theme of the development is rapid prototyping to minimize schedule risk. In addition to leveraging available components and development tools as possible (hence the early survey work), the simulation infrastructure development is centered around building-up the system with near-term, in-house demonstrations. Our experience indicates that small, tangible milestones provide an excellent means to maintain focus and calibrate the team about its progress and the size of the job. To this end, we plan to build up the system an element at a time.

More specifically, Seagull will obtain and run PAS in June. The PAS ICD (Logicon's first deliverable) will guide the development of our initial software interfaces to PAS. The interfaces will be exercised shortly thereafter. By mid-July, Seagull will specify needed modifications to PAS[CAD] and allow Logicon's associated development and validation to occur in parallel with Seagull's other interface definition and development activities.

Interfaces to Lockheed-Martin's Shared Model of Intent (SMI) software will be defined by mid-July. The plan is to exercise the interface mechanism to RTO #5 in August. With the interface defined and exercised, the underlying development activities for RTO #3 and RTO #5 can occur in parallel, with interface testing and modification occurring along the way, as needed.

Seagull will obtain NASA's FASTWIN software and available interface control documentation in June. The software will then be run/exercised in-house. Preliminary tests of the interface will occur thereafter. We plan to use the CDU, FMS, PFD, and Nav display portions of FASTWIN with minimal modification. Refinements will be made to FASTWIN's interfaces to accommodate the information management architecture that Seagull will develop.

In parallel with RTO #5's software development and Logicon's modifications to PAS, Seagull will fill out its distributed, multi-process information management software. As software functionality builds, it will be incrementally tested, as applicable, with PAS, FASTWIN, and the defined interface to RTO #5.

A key point is that the software will be built-up and tested with available components in an incremental manner. The software will be built to the point where complete initial functionality is achieved at Seagull's facility. We strongly prefer not to perform integration all at once, nor do we suggest an all at once delivery to NASA. As compute platforms are brought on-line at NASA LaRC, portions of the software will be made available for preliminary testing at LaRC. The same compute platforms, operating system versions, and development tools will be used for validation tests at Seagull as will be used at LaRC.

<u>TASK – Deliver Software to NASA:</u>

As the final delivery date approaches, simulation infrastructure will be in place in the IDEAS lab at NASA LaRC and in Seagull's simulation laboratory to evaluate various Free Flight concepts. The simulation elements can be configured so the evolving system design can be represented without rebuilding the simulation. The near-term system will include ATC interaction with aircraft having different levels of equipage for ADS-B and Flight Information Services and related concepts.

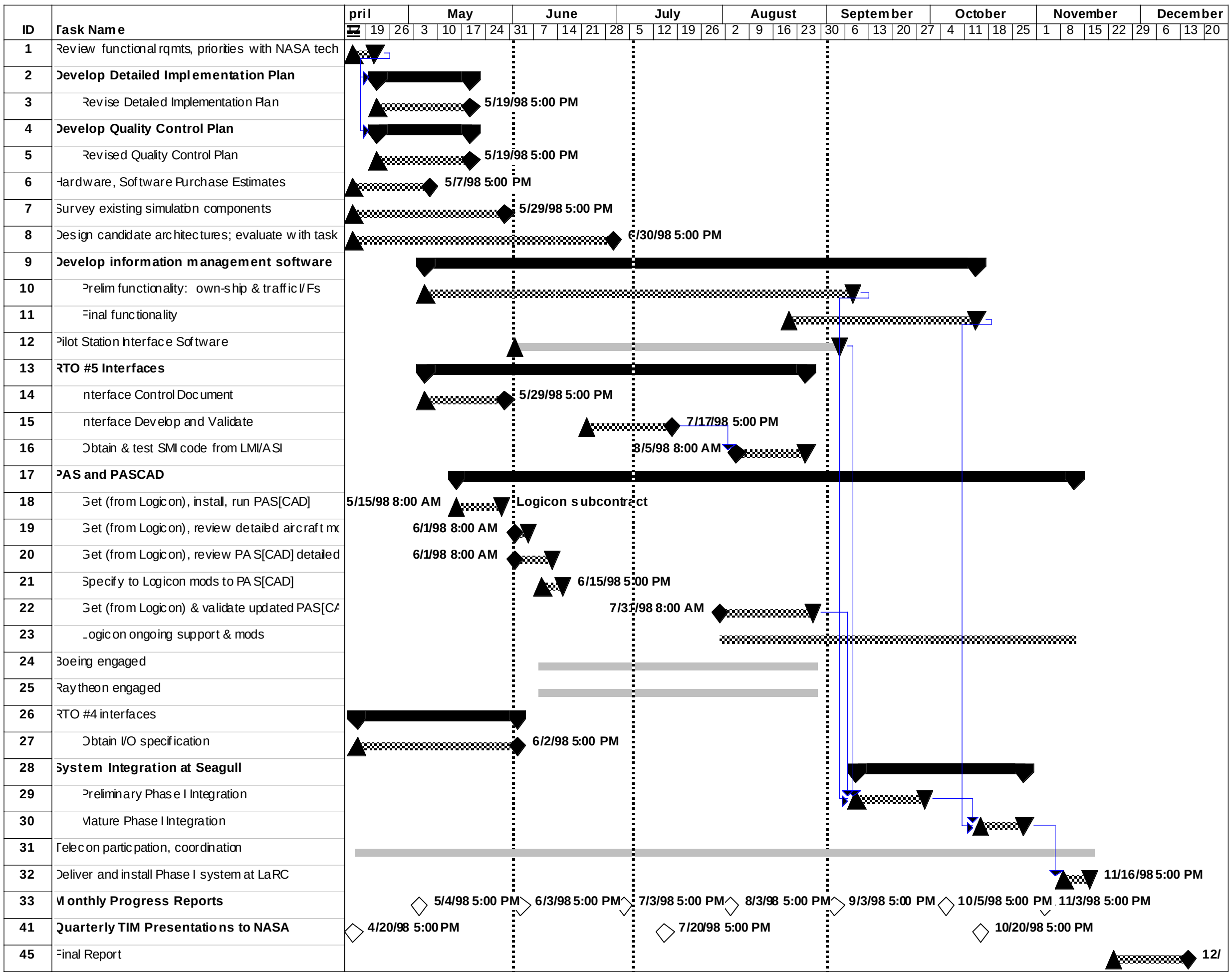
<u>TASK – Write Final Report:</u>

Pending approval from NASA and Honeywell, our plan is to provide a Final Report for the Phase I activity to NASA on or before December 15, 1998. This is after the scheduled software delivery. Our rationale for this is two-fold:

1. We will be delivering software in November. A final report in October is premature. We will be in a more knowledgeable position to write up a suitable final report after we have made the delivery.
2. Delivering a final report by the end of October will interfere with our ability to meet the principal delivery of software.

Schedule and Resources

Below is the schedule of tasks for the AATT FY98 RTO #3 activity. Milestones with deliverables are shown as solid diamonds. Each milestone has an associated date identified. Some milestones are for Seagull's receipt of deliverables from other members on the team. Those milestones are shown at the beginning (time of receipt) of a task.



Expected Results

At the end of this effort, simulation infrastructure will be in place in the IDEAS lab at LaRC and in Seagull's simulation laboratory to evaluate various Free Flight concepts. The simulation elements will be configure-able so the evolving system design can be represented without rebuilding the simulation. The near-term system will include ATC interaction with aircraft having different levels of equipage for ADS-B, Flight Information Services, and related concepts. The architecture will leverage Seagull's experience with traffic management, conflict detection and resolution (CD&R), FMS, flight [re-]planning, and weather avoidance.

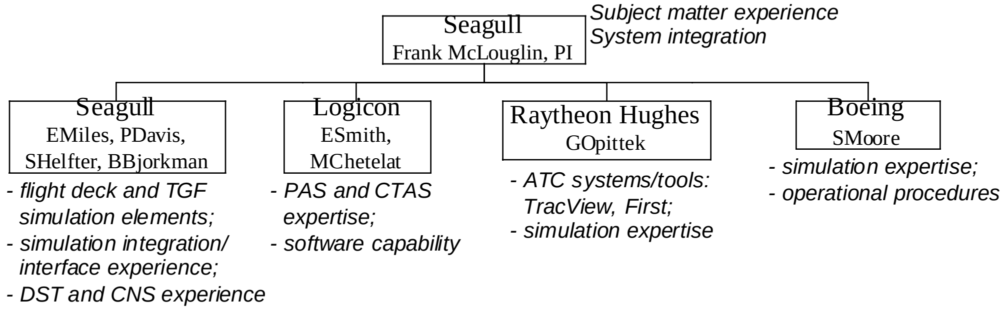
The key features of our rapid prototyping architecture are that its components are re-configurable, reducing risk. Another important feature is that this simulation will be useful for years to come, for it can easily incorporate additional components, such as AOC and flight deck simulators, found at various industry and government laboratories. The simulation is scale-able, both in size and in fidelity, so it can meet the more demanding free-flight simulation requirements likely to arise in later years.

Expertise and Skill Mix

Seagull's team will continue to be lead by Dr. Frank McLoughlin. Dr. Eric Miles will closely assist Frank with systems engineering, architecture, and technical interface support. Mr. Paul Davis is the software lead for a team consisting of himself, Ms. Susan Helfter, and Mr. Bill Bjorkman.

Logicon's team will be lead by Mr. Elliott Smith, rather than Mr. Reed Weske. Logicon's core software development team will continue to provide support under the technical guidance of Monique Chetelat, who has extensive experience with PAS, PASCAD, and associated software components.

Ms. Sally Moore and Mr. Gene Opittek from Boeing and Raytheon-Hughes, respectively, will provide the benefit of their organizations' experience with associated simulation and air traffic control tools and products. They will primarily provide oversight and review of the development.



Additional Issues

Seagull personnel plan to use the following tools during the development process:

- Visio Technical v4.5
- Rational Rose

It is suggested that NASA and/or other organizations consider the use of these tools for the sake of compatible communications.

Procurement Costs

A hardware and software procurement list was provided as a deliverable on 30 June 1998. A revision of that document was delivered on 1 July 1998 to the NASA COTR and technical monitor, as well as to interested industry participants.